

Evaluation of Microcomposite Coatings for Chrome Replacement



2 Sep 2009

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Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 02 SEP 2009		2. REPORT TYPE		3. DATES COVERED 00-00-2009 to 00-00-2009	
4. TITLE AND SUBTITLE Evaluation of Microcomposite Coatings for Chrome Replacement				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Research Laboratory, Wright Patterson AFB, OH, 45433				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES ASETSDefense 2009: Sustainable Surface Engineering for Aerospace and Defense Workshop, August 31 - September 3, 2009, Westminster, CO. Sponsored by SERDP/ESTCP.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 32	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			



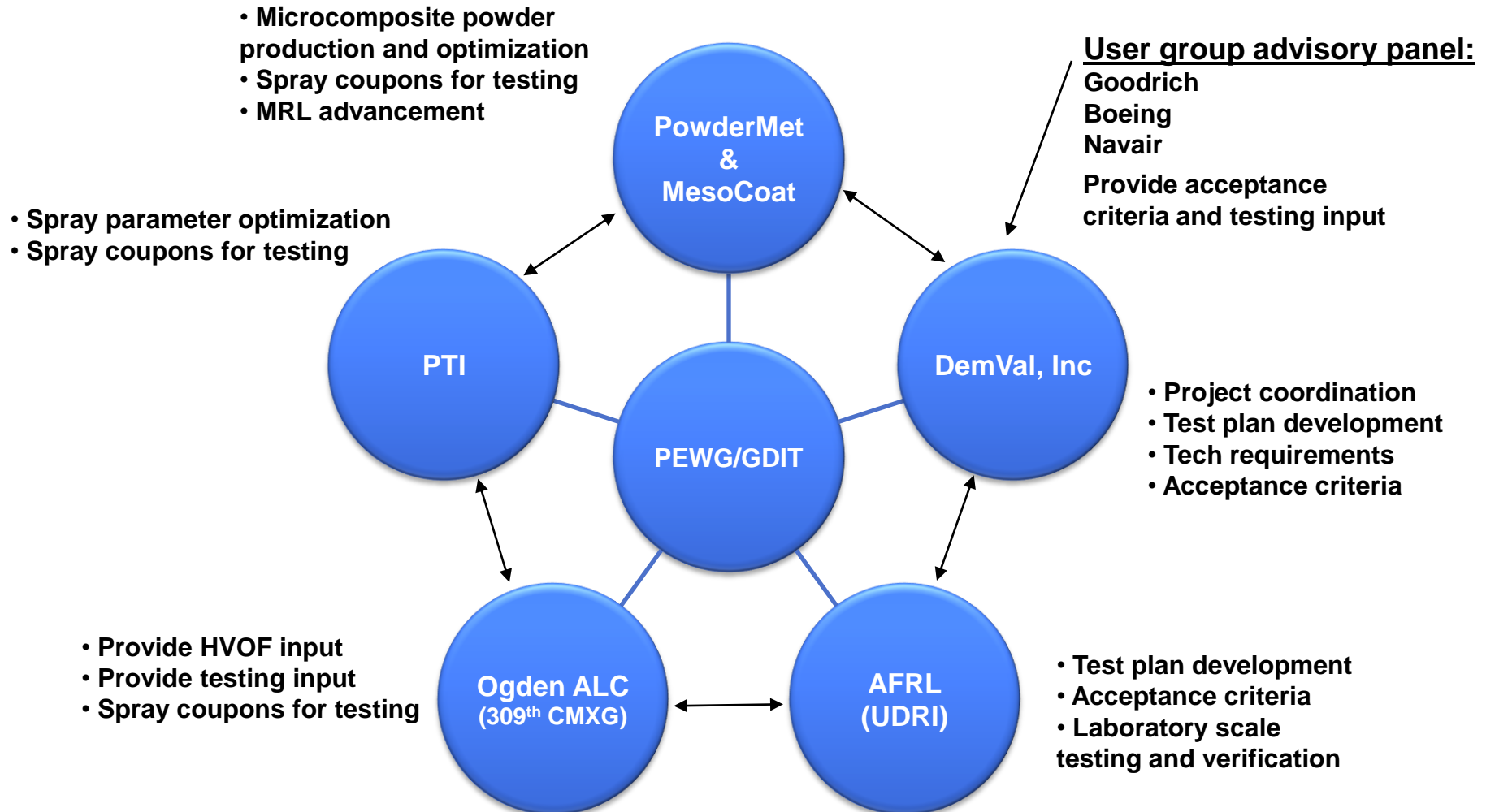
Outline



- **John Kleek, AFRL**
 - ✓ Program Organization
 - ✓ AFRL (UDRI) Test Plan
 - ✓ Preliminary Test Results
- **Greg Engleman, MesoCoat, Inc.**
 - ✓ Microcomposite Coating Development
 - ✓ Value Propositions
 - ✓ Microcomposite Coatings
 - ✓ Screening Results



Low Density (Microcomposite) Coatings LP752 Project Organization





Microcomposite Coatings for Chrome Replacement (PEWG Project LP752)



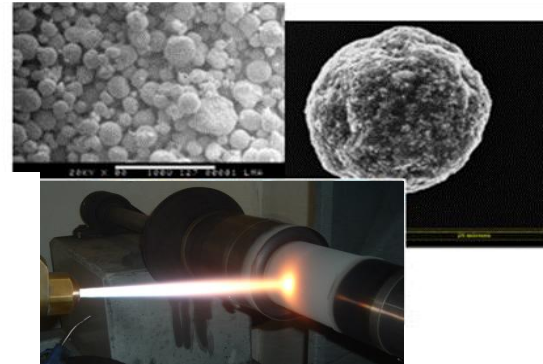
Problem Statement:

- Tungsten carbide cobalt (WC-Co) coatings that replaced Hard Chrome on landing gears
 - Costs more
 - Weighs more
 - Requires diamond grinding for desired surface finish
 - WC-Co coating has a tendency to spall at high stress

NOTE:

- This project is NOT a NEW Technology
- It is a drop-in replacement using HVOF equipment
 - Uses an ALTERNATIVE powder source
- It does NOT require training or capital equipment

Microcomposite (SiN) powders for HVOF processing



HVOF Thermal Spray



Landing Gear

Partners

GDIT (PEWG)

DemVal, Inc.

AFRL

OO-ALC (309th CMXG)

PowderMet, MesoCoat

PTI

UDRI (AFRL)

Roles

Program Leadership & Admin

Proj Mgt & Test Plan Dev

Test Plan Dev (HCAT JTP)

Provide HVOF and testing input

Powder Man/Thermal Spray Proc

HVOF Thermal Spray Development

Testing & Verification of Coating

Benefits/Payoff:

- Microcomposite (low density) coatings will offer:
 - 60% weight reduction compared to WC-Co
 - 30-50% material cost savings over WC-Co
 - Better coating integrity – no spallation
 - 1.5% ductility with no cracking or spallation
 - Better corrosion protection
 - Improved wear resistance
 - Improved fatigue resistance – increased part life
 - No need for diamond grinding

AFRL Lead: John Kleek, 937-656-6064

Customer(s): Ogden ALC; Tinker AFB; OEM's; NAVAIR



Test Plan



- **Screening Tests**

Qty

PowderMet

✓ Bend Test (tensile)

as req

✓ Bond Adhesion, ASTM C633

as req

✓ Metallography (porosity, hardness, unmelts)

as req

✓ Salt fog corrosion, ASTM B-117

12

✓ Spallation (Big Bar), HCAT JTP

5

✓ Wear (sliding piston), HCAT JTP

6

✓ Impact Gravelometer, ASTM D3170

4

**AFRL
(UDRI)**

- **Other Tests**

✓ Grinding Capability

✓ Fluid Compatibility

✓ Coating Stripability

✓ Tensile with Acoustic Emission

**AFRL
(UDRI)**



Test Plan (cont.)



<u>Acceptance Tests</u>	<u>AFRL</u>	<u>Metcut</u>
✓ Spallation (Big Bar), HCAT JTP	10	5
✓ Salt fog corrosion testing, ASTM B-117	16	8
✓ Wear (sliding piston), HCAT JTP	18	6
✓ Fatigue (R=-1), ASTM 466-96	80	20
✓ Hydrogen Embrittlement, ASTM F519-97	20	8
✓ Impact, Gravelometer, ASTM D3170	9	-
✓ Almen N Testing	10	-

Notes:

1) 4340 (Rc=53) will be used for all the testing above except fatigue and spallation tests where 300M (280-300 ksi) will be used.

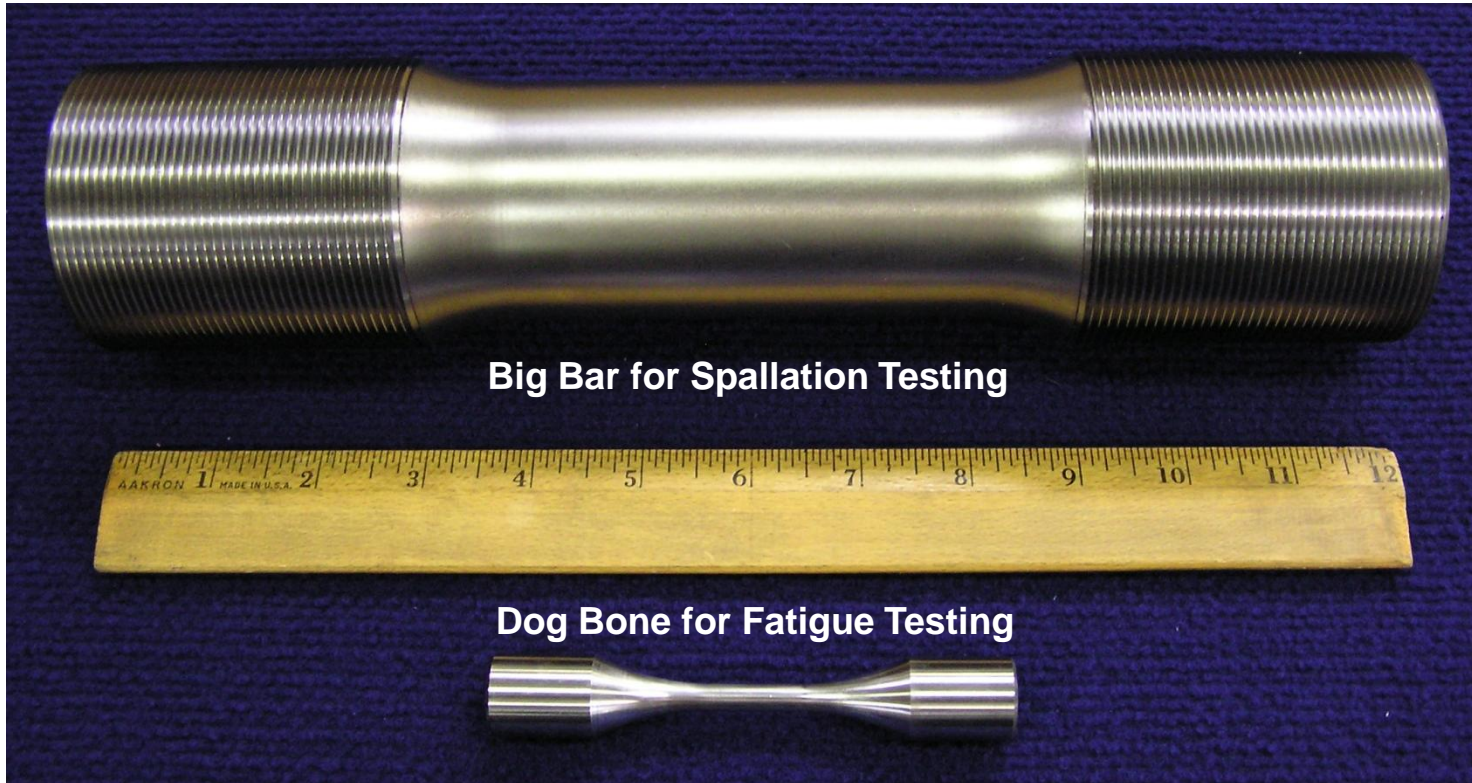
2) The results of the above tests must be equal to or better than Chrome (EHC).

3) There will be some testing performed by Metcut Research in addition to the above testing by UDRI for confirmation purposes and for adding to the database.

4) The above plan & quantities listed above have been coordinated with OO-ALC (309th CMXG) and other stakeholders and is acceptable.



Primary Test Specimens



Big Bar for Spallation Testing

Dog Bone for Fatigue Testing

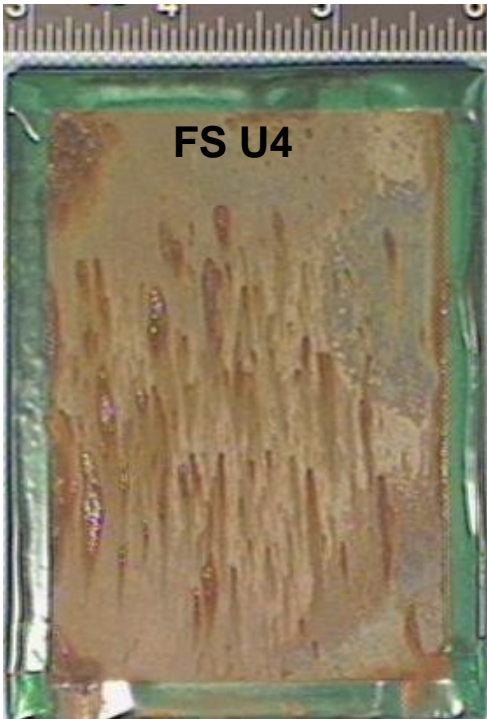


Preliminary Screening Results

✓ Corrosion (3 Weeks Exposure, 504 hrs)

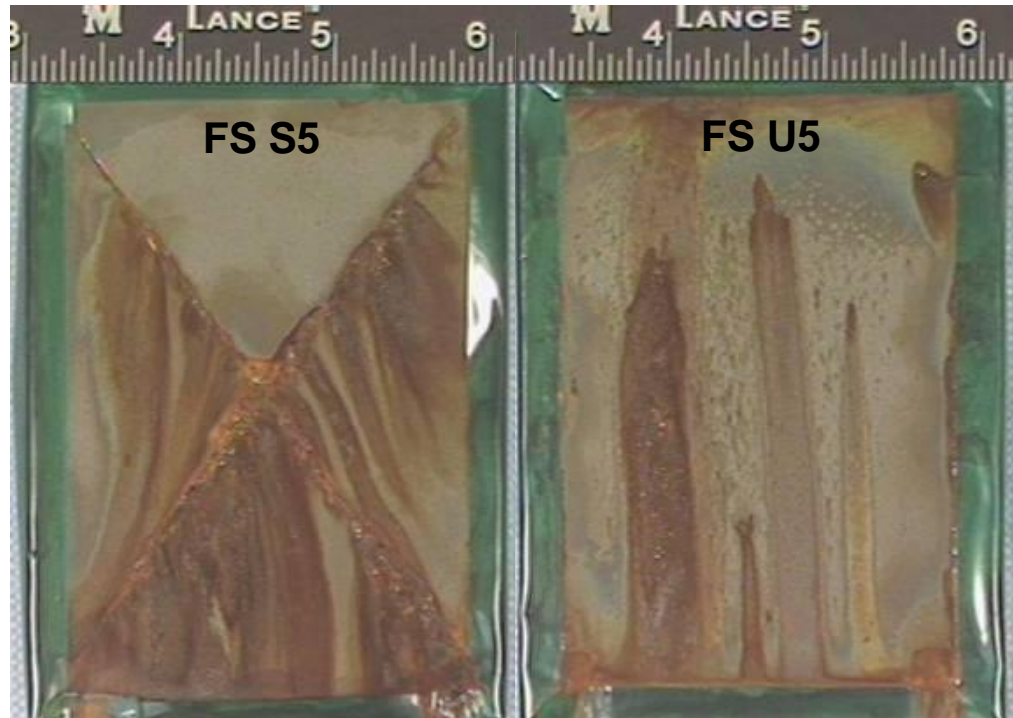
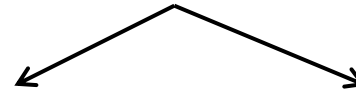
PCoMP-S

Jet-Kote sprayed at PTI



PCoMP-S

DJ-Hybrid sprayed at MesoCoat



Some corrosion pits related to coating porosity, indication of coating quality.

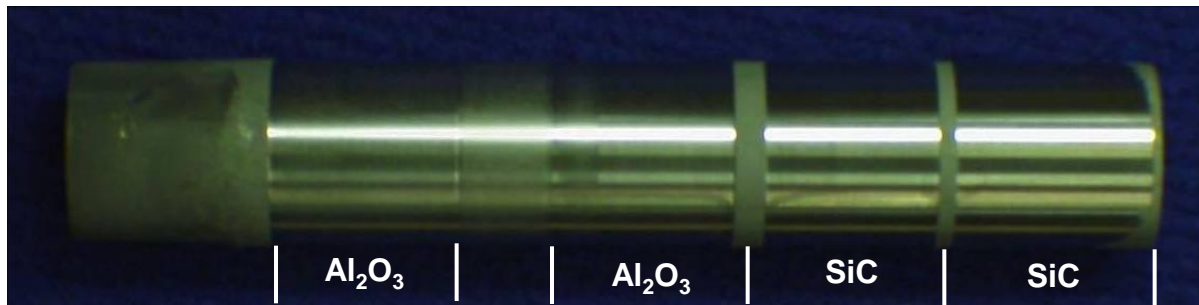


Preliminary Screening Results



✓ Grinding

- Initial Grinding results very positive.
- No diamond wheel necessary.
- Used wheels typically used for chrome (EHC)
 - Speeds and Feeds typical for EHC grinding
 - Type L Al_2O_3 80 grit wheel
 - Surface finish, $R_a \sim 14 \mu\text{inch}$
 - Type J SiC 100 grit wheel
 - Surface finish, $R_a \sim 6 \mu\text{inch}$
- Grinding was plunge and (short) traverse





Summary of Testing & Results



- **Test plan developed from prior HCAT work and JTP's.**
 - ✓ Acceptance criteria provided by OO-ALC (309th CMXG) and other stakeholders/customers.
- **Preliminary screening testing underway...**
 - ✓ Corrosion results look good and will be used to develop improved spray parameters which will decrease porosity.
 - ✓ Grinding results are excellent using SiC wheel. No need for diamond grinding.
- **Big Bar samples for spallation and fatigue bars have been machined and are ready for thermal spraying.**
 - ✓ Screening tests including spallation are planned for mid Sep.
 - ✓ Other screening tests including corrosion, wear, and impact testing also planned to start in Sep.
- **Full acceptance testing is planned for later this year.**



POWDERMET INC.

The Cutting Edge in Metal Powder Technology

PComP™: Microcomposite Cermet Coatings for Chrome Replacement

***ASETSDefense '09
Denver, CO***

September 1-3, 2009

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Project Objective

- **Demonstrate and Validate micro-composite coatings for the replacement of chrome on DoD systems that meets or exceeds the requirements for hard chrome and is lighter and more strain tolerant/spallation resistant than current WC-Co materials.**

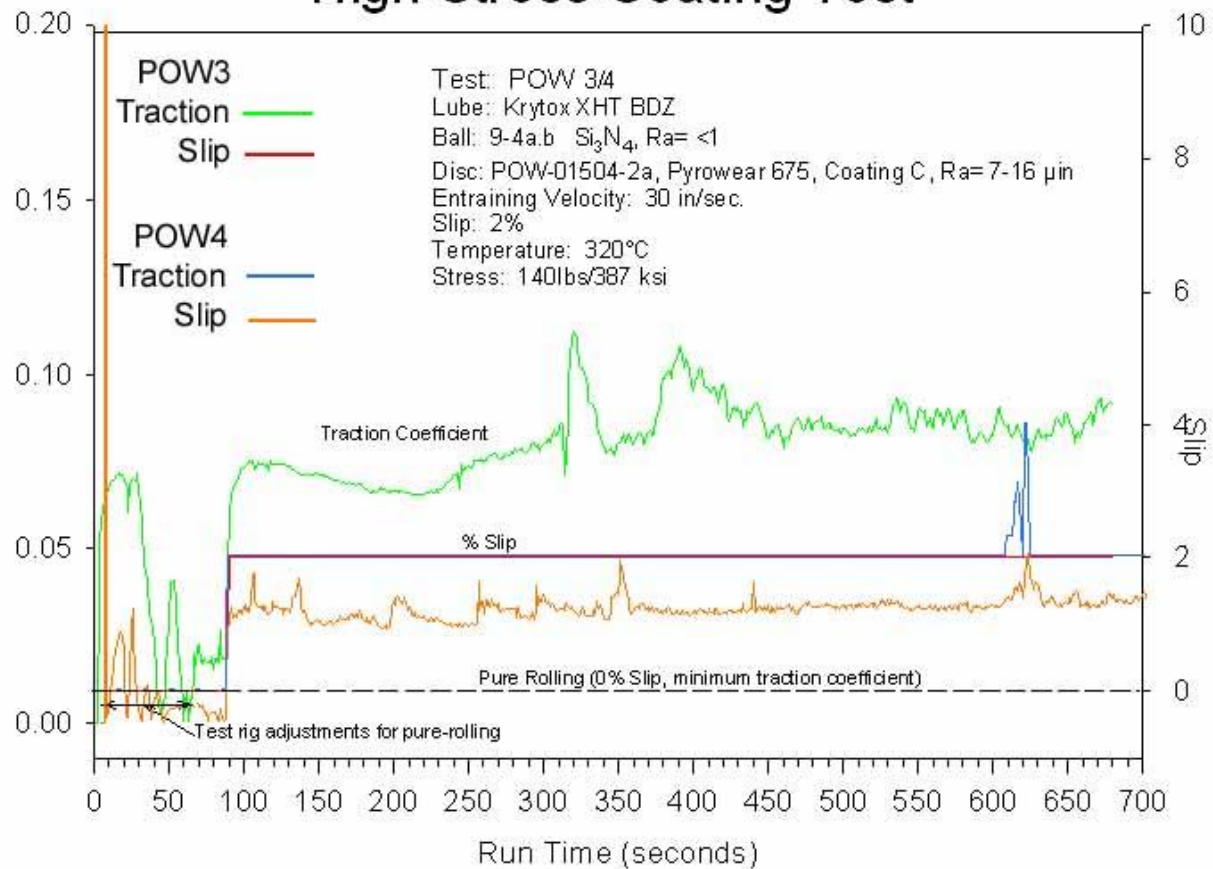


WAM-4 simulated bearing tests

- **Grease Lubricant: DuPont Krytox XHT-BDZ**
- **Contact Stress: 387Ksi**
- **Ball Size: 13/16" diameter silicon nitride balls**
- **Entraining Velocity 30 in/sec**
- **Sliding Velocity : 0.6 in/sec (2% slip)**
- **Temperature: 320°C**
- **Test length: 600 seconds**
- **7 tests performed**



WAM3 Slow Speed High Stress Coating Test

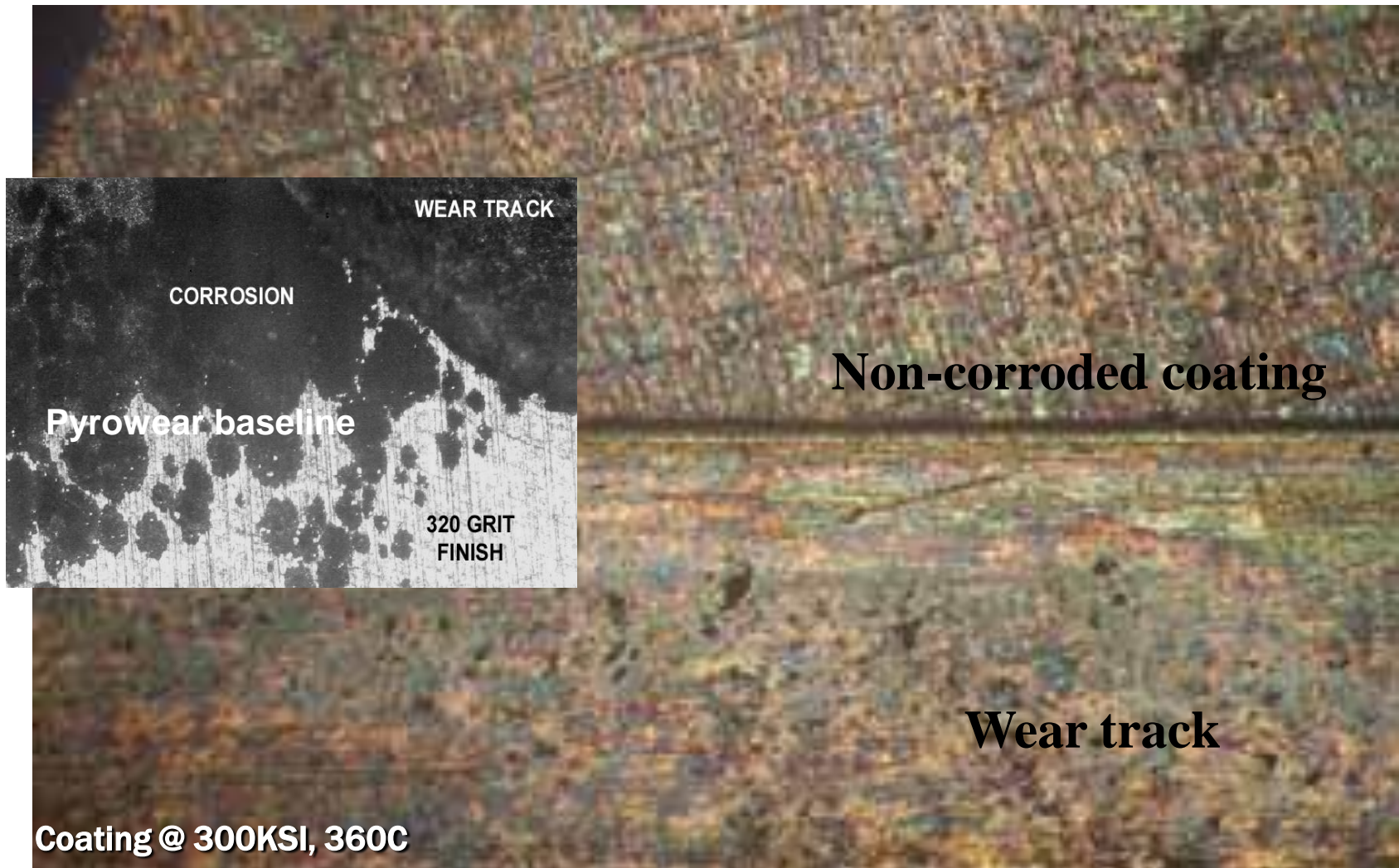


<<testing\powdermet\pow jnb>>



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WAM-4 Wear Test



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Value Propositions

- Low density, domestic source, drop in replacement for WC-Co
 - Reduced weight drives fuel consumption down
- Reducing repair costs reduces total operational cost
- Increasing repair cell throughput
 - Increased coverage
 - Improved machining/grinding
- Meet carrier based landing gear and other highly stressed component coating requirements
- Spallation resistant



Work Plan

- **Develop and produce a nano-/micro-composite cermet coating**
 - **Complete quality plan and sensitivity analysis**
- **Develop coating application parameters**
- **Develop acceptance criteria and joint test protocol**
- **Apply coating to test coupons**
- **Test coated coupons**



Partners

- Propulsion Environmental Working Group (PEWG)

- Project Managers



- DemVal, Inc.

- Demonstration and Validation, JTP
- Project Coordination



- Plasma Technologies, Inc.

- Thermal Spray Application



- WPAFB/AFRL/UDRI

- Testing



- Powdermet/MesoCoat

- Powder Production
- Application Parameter Development



Microcomposite Coating Materials Approach

- **Combine hardness of lightweight ceramic with ductility and toughness of metal**
 - **Start with low cost, lightweight ceramic**
 - **Blend and Spray-dry with corrosion resistant ductile metal alloy binder**
 - **Encapsulate with additional matrix for improved toughness/ductility**
 - **Micron-scale “lamella” in coating to allow for dislocation motion (ductility)**
 - **Thermal spray to form ductile wear and corrosion resistant coatings.**
 - **Patent-pending materials technology**



Microcomposite Coating Features

	Micro-Composite Coatings	Chrome Plate	WC-Co-Cr thermal spray
Coating density	4-5g/cc (low)	9g/cc (medium)	17g/cc (very high)
Total coating cost	Less than 1X	Baseline (1X)	2X
Modulus	20-30MSI	0 (cracked)	65 MSI
Gun throughput	>3X	Days to coat	1X
Surface finishing costs	SiC or alumina wheel	Alumina wheel	Diamond wheel
Ductility	4%	<0% (cracked)	<1%
Wear Performance	10X chrome	1X chrome	3X chrome
Thickness limitations	>40 mils	3-5 mils	10-20 mils



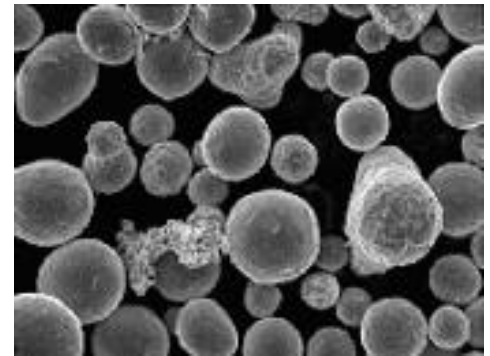
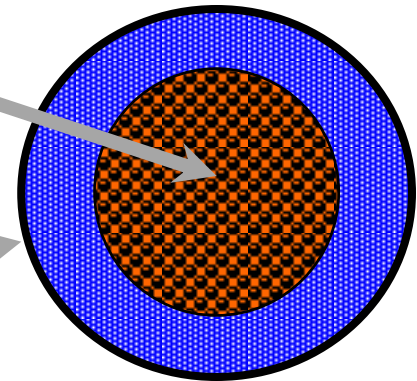
Powdermet's Breakthrough Material Technology

- **Near-Nano Composite Core**

- Increases thermal gradient
- Decreases thermal stress
- Improves resilience

- **Binder Coating**

- Improves adhesion
- Provides toughness and resiliency
- Provides corrosion resistance and bonding

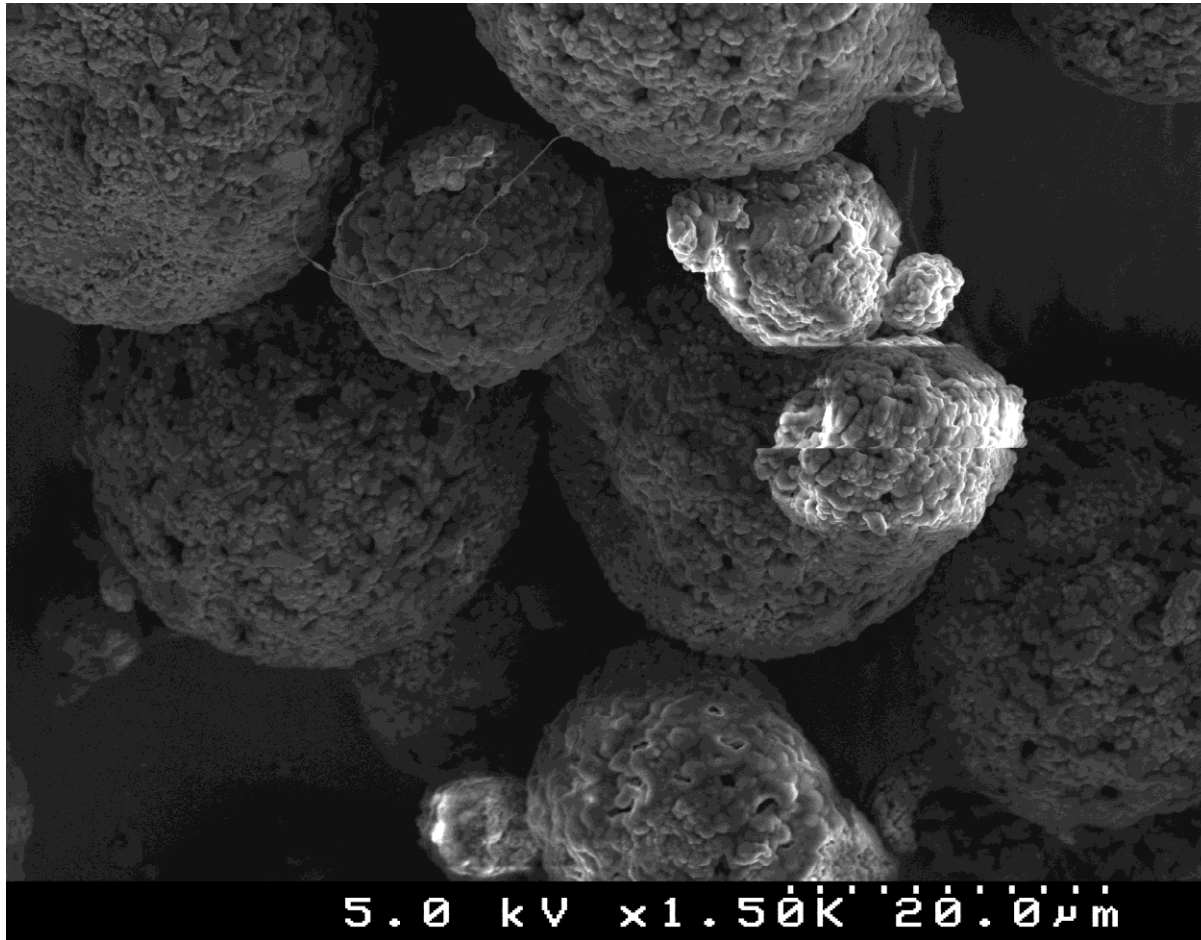


PComP™-S

- **Drop-In Replacement for Thermal Spray Feedstocks**
- **Strain tolerant (>2% strain to failure)**
 - **Improved spallation resistance**
- **Reduced Density (5.0-6.0 g/cm³)**
- **Doesn't Require Special Tooling**
 - **No Diamond/CBN Grinding**
- **Low Density, Friction, and modulus**



PComP™-S



POWDERMET INC.

Coating Specifications

- **Strain to failure >1.5%**
 - Compares to yield stress in 4340M of 0.35%
- **Porosity, unmelts less than 1%**
- **Hardness 700-800VHN**
 - Lower hardness is poor coating, higher hardness means less strain tolerant)
- **Adhesion >10,000 psi**



Screening

- **Screening trials**

- Bend coupons (compressive and tensile, repeat bend).
- Coating adhesion
- ASTM B-117 salt fog corrosion testing
- Big bar fatigue testing

- **Met Testing**

- Metallographic analysis
- Porosity, hardness, unmelts, etc.

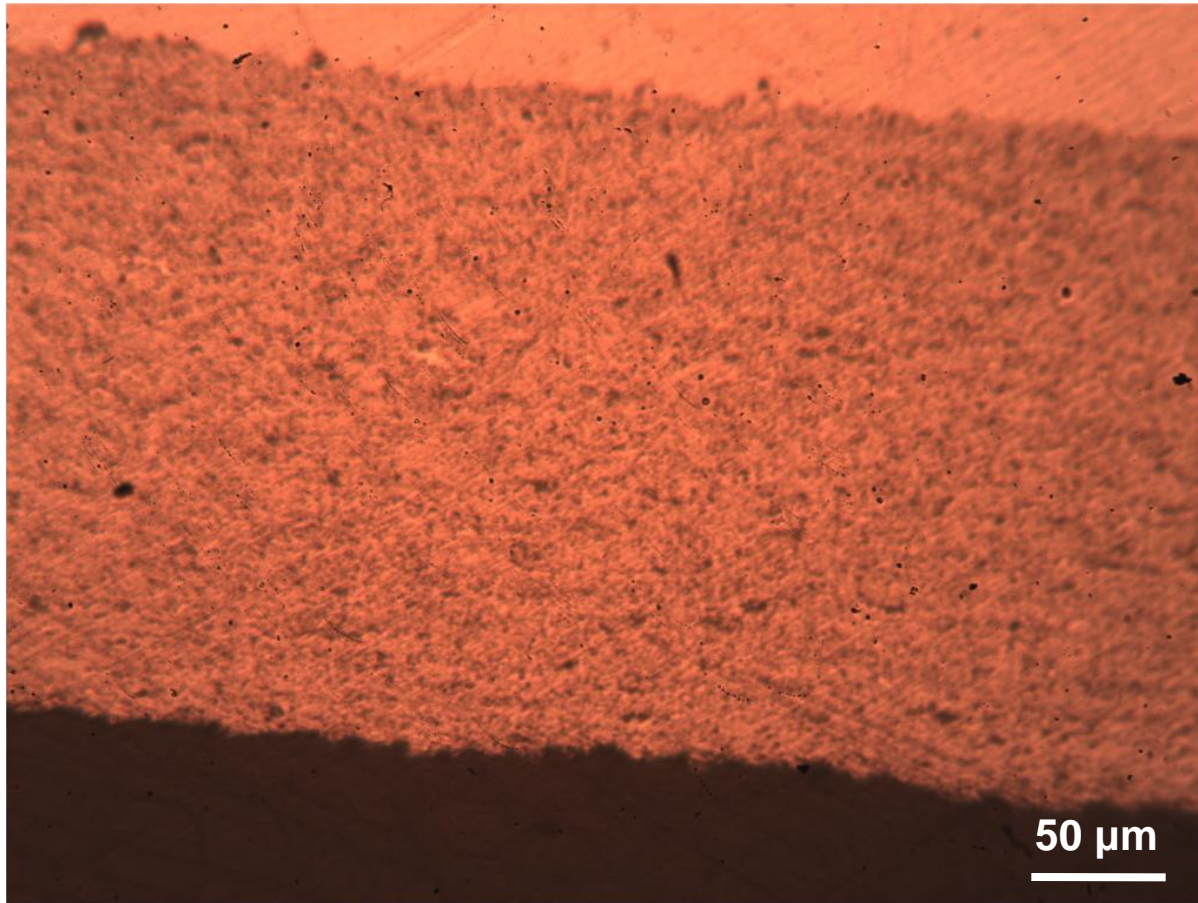


Screening Test Findings

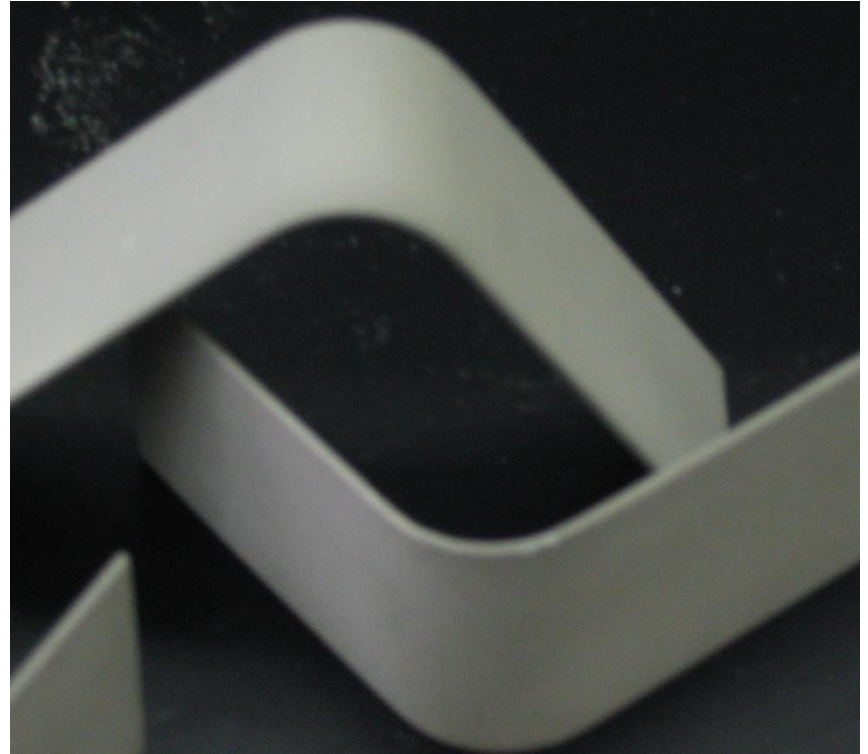
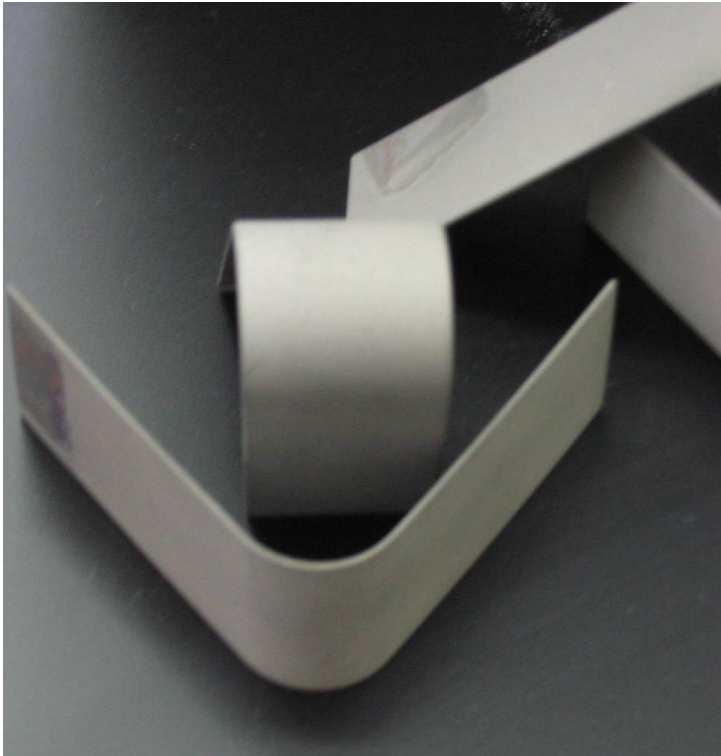
- Higher Ceramic content, finer particle size increase hardness but decrease strain to failure
- Increased Cr content increases hardness, decreases strain tolerance
- Hardnesses achieved (fully dense coating) range from 650 to 900 VHN
- Strain to failure measured from 0.3 to 6%.
- Difficult to get significant residual stress in coating (low modulus)



Micrograph



Bend Test Coupons



Coating Analysis

Property	Method	Target	Typical
Thickness	Image Analysis, Average of 5 measurements	10 mils	8 – 12 mils
Interface Continuity	% of total interface length	> 95%	97 - 100%
Porosity	% of total area	< 1%	0.4 – 0.6%
Globular Particles	Number per coating area	< 1.5 E -4 / μm^2	2.9 E -5 / μm^2
	% of total area	< 1%	0.33%
Hardness	10 point average	700 – 800 HV ₃₀₀	725 - 790 HV ₃₀₀
Adhesion Bond Strength	ASTM C 633	> 10,000 psi	11,000 – 13,500 psi



POWDERMET INC.

Questions?

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